MARMARA
MEDICAL JOURNAL

Original Article

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Assessment of heart rate variability in elderly patients with type 2 diabetes mellitus

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Submitted: 19.02.2025 **Accepted:** 24.03.2025

ABSTRACT

Objective: Cardiac autonomic neuropathy (CAN) is a prevalent complication of type 2 diabetes mellitus (DM) and is associated with elevated cardiovascular risk. The objective of this study was to evaluate changes in heart rate variability (HRV) in elderly patients with type 2 DM and to investigate its relationship with laboratory findings.

Patients and Methods: The present retrospective study comprised 182 subjects aged ≥65 years who underwent 24-hour Holter ECG monitoring. Patients were divided into two groups: a DM group (n=72) and a control group (n=110). HRV parameters in both time and frequency domains were analyzed, and their correlations with laboratory markers were evaluated.

Results: Heart rate variability parameters, including standard deviation of SDNN (p=0.004), SDANN (p=0.008) and SDNN index (p=0.015), were found to be significantly lower in DM. Furthermore, a decline in frequency domain parameters, including POWER (p=0.004), VLF (p=0.006), LF (p =0.007) and HF (p=0.049), was observed. In addition, a negative correlation was identified between HRV and inflammatory markers, such as white blood cell (WBC) count (p <0.001).

Conclusion: Reduced HRV in elderly diabetic patients suggests autonomic dysfunction and increased cardiovascular risk. The inverse correlation between HRV and inflammatory markers highlights the potential role of systemic inflammation in autonomic impairment.

Keywords: Heart rate variability, Diabetes mellitus, Diabetic neuropathies, Aged, Heart disease risk factors, Autonomic nervous system

1. INTRODUCTION

Cardiac autonomic neuropathy (CAN) is a prevalent and rigorous complication of type 2 diabetes mellitus (DM), associated with elevated cardiovascular mortality [1]. It originates from a dysfunction of the autonomic nervous system that impairs the balance between sympathetic and parasympathetic activity [2]. Consequently, heart rate variability (HRV) reduces considerably, and low HRV levels are significantly associated with cardiac arrhythmias, sudden cardiac death, and other cardiovascular events [3].

While, HRV decreases with age, some studies have shown that this decrease is more pronounced in individuals with DM [4,5]. The Ikaria study found an association between lower HRV levels and increased arterial stiffness and vascular dysfunction in elderly non-hypertensive individuals [6]. Similarly, the PROOF study found that metabolic syndrome reversely affects HRV parameters in elderly individuals with DM [7]. Reduced HRV levels have been associated with poor clinical outcomes in patients with DM [8]. Accordingly, the study by May et al., identified HRV as a strong predictor of mortality [9]. Due to the scarce data examining changes in HRV in elderly individuals with type 2 DM, more research is needed to fill the gap in this area.

The objective of the present study was to assess alterations in HRV among individuals aged 65 years and older with type 2 DM, and to examine the relationship between these changes and laboratory parameters. This study suggests that HRV is significantly reduced in elderly individuals with type 2 DM and that this reduction may be related to laboratory parameters .

2. PATIENTS and METODS

The present study was conceived as a retrospective observational study and was conducted in accordance with the Declaration of Helsinki. The study protocol was approved by the Marmara University, School of Medicine Ethics Committee (date:31/01/2025, approval number:9.2025-25-0060). Patient data were retrospectively obtained from the hospital record system.

Patients who presented to the Cardiology Department between January 2024 and October 2024 and underwent 24-hour Holter ECG monitoring were evaluated retrospectively. All patients aged 65 years and older who underwent 24-hour Holter ECG monitoring during the study period were consecutively included. After applying the exclusion criteria, the remaining 182 patients were classified into two groups

How to cite this article: Demirci M, Sunbul M. Assessment of heart rate variability in elderly patients with type 2 diabetes mellitus. Marmara Med J 2025;38 (2): 108-113. doi: 10.5472/marumj.1708027

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ISSN: 1309-9469

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based on diabetic status: a DM group (n=72) and a control group (n=110) (Figure 1). Patients with permanent pacemakers, chronic atrial fibrillation, paroxysmal atrial fibrillation (PAF) detected by Holter ECG, diagnosed hypothyroidism, ventricular tachycardia, poor quality Holter ECG recordings, moderate or severe valvular heart disease, or hyperthyroidism were excluded from the study. Individuals aged 65 years and older who were diagnosed with type 2 DM according to the American Diabetes Association (ADA) criteria were included in the study [10]. A detailed medical history, demographic, clinical characteristics and laboratory parameters were collected from all participants.

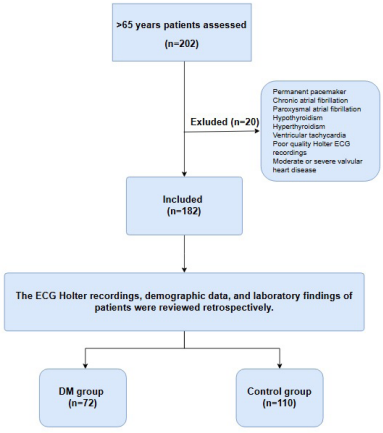

Figure 1: *Flow chart of the participants.*

Heart Rate Variability

Holter-ECG recordings were obtained using the DMS 9800 (USA) model miniature ambulatory ECG monitoring device with three leads and digitized at a sampling rate of 128 Hz over a 24-hour period. HRV analyses were conducted using the commercially available Cardioscan 12.0 (DMS, USA) software. The time-domain analysis comprised the standard deviation of normal-to-normal (NN) RR intervals (SDNN), the standard deviation of the average NN RR intervals calculated in 5-minute segments (SDANN), and the mean of the standard deviations of all NN RR intervals for each 5-minute segment over a 24-hour period (SDNN index). Additionally, the root mean square of successive differences between adjacent NN RR intervals (RMSSD) and the percentage of NN RR interval differences greater than 50 ms (pNN50) were calculated. In the frequency-domain analysis, total power (POWER) represented overall HRV variability, while the low-frequency component (LF: 0.04–0.15 Hz) reflected both sympathetic and parasympathetic activity, with a slight predominance of sympathetic activity. The high-frequency component (HF: 0.15–0.40 Hz) represented vagal activity, while the LF/HF ratio indicated the sympathovagal balance and, consequently, the dominance of sympathetic activity.

Holter-ECG recordings were subjected to review by a cardiologist who was unaware of the patient's medical history and all non-normal RR intervals were manually inspected in order to assess the quality of the recording. Recordings which exhibited an artefact rate in excess of 2% were excluded from further analysis. Only recordings which had been monitored for a minimum of 20 hours and which exhibited sufficient quality for assessment were included in the final analysis. HRV analyses were conducted in accordance with the standards established by the European Society of Cardiology (ESC) [11].

Statistical Analysis

Statistical analyses were conducted utilising SPSS version 22.0 for Windows (Chicago, IL, USA). Continuous variables were subjected to a Kolmogorov-Smirnov test to ascertain their distribution and were subsequently expressed as mean ± standard deviation. Where relevant, differences between continuous variables were analysed by means of either the independent samples Student's t-test or the Mann-Whitney U test. Categorical data were presented as counts or percentages, and the chi-squared test was employed to compare categorical variables. Pearson's correlation coefficient was calculated between HRV and laboratory parameters. A linear regression analysis was conducted to identify the predictors of SDNN, and variables with a p-value of less than 0.05 in the univariable analysis were included in the multivariable analysis.

3. RESULTS

A total of 182 patients were enrolled, 72 in the DM group and 110 in the control group. There was no significant difference in the mean age between the groups (70.58 ± 4.24 vs. 71.52 ± 4.16, p=0.143). The DM group demonstrated a higher prevalence of hyperlipidaemia and the use of statin therapy. However, other demographic characteristics and medication use exhibited no significant differences between the groups. The demographic and clinical characteristics of the study groups are outlined in Table I.

Table I. *Demographic and clinical characteristics of study groups*

Characteristics	DM (n=72)	Control (n=110)	p-value
Age (years)	70.58 ± 4.24	71.52 ± 4.16	0.143
Male gender, n (%)	43 (59.7)	61 (55.5)	0.569
HT, n (%)	59 (81.9)	79 (71.8)	0.119
HL, n (%)	48 (66.7)	49 (44.5)	**0.003**
Stroke, n (%)	23 (31.9)	26 (23.6)	0.217
Active smoking, n (%)	15 (20.8)	16 (14.5)	0.270
CAD, n (%)	30 (41.7)	34 (30.9)	0.137
LV EF (%)	57.63 ± 9.49	59.67 ± 7.80	0.133
Antiplatelet therapy, n (%)	43 (59.7)	54 (49.1)	0.160
OAC, n (%)	10 (13.9)	14 (12.7)	0.821
ACEi/ARB, n (%)	48 (66.7)	62 (56.4)	0.165
BB, n (%)	25 (34.7)	39 (35.5)	0.919
CCB, n (%)	23 (31.9)	28 (25.5)	0.340
Diuretics, n (%)	21 (29.2)	26 (23.6)	0.405
Statin, n (%)	44 (61.1)	42 (38.2)	**0.002**
OAD, n (%)	58 (80.6)	NA	NA
Insulin, n (%)	19 (26.4)	NA	NA

ACEi: Angiotensin-converting enzyme inhibitor, ARB: Angiotensin receptor blocker, BB: Beta-blocker, CAD: Coronary artery disease, CCB: Calcium channel blocker, DM: Diabetes mellitus, HL: Hyperlipidemia, HT: Hypertension, LV EF: Left ventricular ejection fraction, NA: Not applicable, OAC: Oral anticoagulant, OAD: Oral antidiabetic drug. Continuous variables are presented as mean ± standard deviation (SD), and categorical variables are expressed as n (%).

Table II presents the laboratory findings of the study groups. White blood cell (WBC) count (9.18 ± 3.42 vs. 7.52 ± 2.39, p=0.001) and

http://doi.org/10.5472/marumj.1708027
Marmara Med J 2025;38(2): 108-113

platelet count (274.89 ± 99.92 vs. 241.76 ± 82.54, p=0.027) were significantly higher in the DM group. While, total cholesterol and LDL cholesterol levels were lower in diabetic patients (p<0.001), as expected, HbA1c and fasting blood glucose levels were significantly higher in the DM group (p<0.001). HDL cholesterol levels were similar between the groups (DM: 51.80 ± 13.39 mg/dL vs. Control: 54.19 ± 14.08 mg/dL, p=0.307).

In the DM group, the mean heart rate (72.90 ± 10.07 vs. 68.14 ± 8.78, p=0.001) and minimum heart rate (50.93 ± 10.08 vs. 47.27 ± 7.99, p=0.007) were significantly higher compared to the control group. With regard to HRV parameters, the DM group represented significantly lower values for SDNN (104.31 ± 36.21 vs. 118.74 ± 30.20, p=0.004), SDANN (92.22 ± 33.73 vs. 104.58 ± 28.38, p = 0.008) and SDNN index (40.92 ± 16.02 vs. 46.99 ± 16.60, p=0.015) compared to the control group. With regard to frequency components, POWER (p=0.004), VLF (p=0.006), LF (p=0.007), and HF(p=0.049) values were significantly lower in the DM group. However, no significant difference was observed between the groups in the LF/HF ratio (p=0.820). The details of HRV parameters are summarised in Table III.

Several significant correlations were identified between HRV parameters and laboratory values. SDNN, SDANN and SDNN index yielded a negative correlation with WBC count (p<0.001). HDL cholesterol levels showed a positive correlation with SDNN and SDANN (SDNN: r = 0.220, p = 0.008; SDANN: r = 0.230, p = 0.006). Conversely, triglyceride levels exhibited a negative association with SDNN, SDANN and SDNN index (p<0.05). Hemoglobin levels demonstrated a positive correlation with SDNN and SDANN (p<0.05). Finally, platelet count represents a negative correlation with SDNN and SDANN (p<0.05). LF and HF were found to be inversely related to WBC count (p=0.016 and p=0.013, respectively), while no significant association was observed with the LF/HF ratio. The results of the correlation analysis are comprehensively summarised in Table IV.

Table II. *Comparison of laboratory findings between DM and control groups*

Parameter	DM (n=72)	Control (n=110)	p-value
HbA1c (%)	7.07 ± 1.30	5.80 ± 0.38	**<0.001**
FBG (mg/dL)	133.93 ± 47.21	99.56 ± 16.39	**<0.001**
Creatinine (mg/dL)	1.03 ± 0.41	0.95 ± 0.34	0.237
AST (U/L)	24.50 ± 17.27	22.20 ± 7.79	0.268
ALT (U/L)	18.93 ± 8.06	18.27 ± 12.26	0.710
Potassium (mmol/L)	4.39 ± 1.11	4.42 ± 0.43	0.807
WBC ($\times10^3$/µL)	9.18 ± 3.42	7.52 ± 2.39	**0.001**
Hemoglobin	13.08 ± 1.84	13.27 ± 1.61	0.501
Platelet count ($\times10^3$/µL)	274.89 ± 99.92	241.76 ± 82.54	**0.027**
Triglyceride (mg/dL)	140.39 ± 84.81	124.70 ± 61.57	0.202
Total-C (mg/dL)	176.67 ± 34.63	205.68 ± 48.50	**<0.001**
HDL-C (mg/dL)	51.80 ± 13.39	54.19 ± 14.08	0.307
LDL-C (mg/dL)	96.37 ± 27.90	126.57 ± 41.37	**<0.001**

ALT: Alanine aminotransferase, AST: Aspartate aminotransferase, DM: Diabetes mellitus, FBG: Fasting Blood Glucose, HbA1c: Hemoglobin A1c, HDL-C: High-density lipoprotein cholesterol, LDL-C: Low-density lipoprotein cholesterol, Total-C: Totalcholesterol, WBC: White blood cell count. Continuous variables are presented as mean ± standard deviation (SD).

Table III. *Comparison of HRV parameters between DM and control groups*

Parameter	DM (n=72)	Control (n=110)	p-value
Mean Heart Rate (bpm)	72.90 ± 10.07	68.14 ± 8.78	**0.001**
Minimum Heart Rate (bpm)	50.93 ± 10.08	47.27 ± 7.99	**0.007**
Maximum Heart Rate (bpm)	115.82 ± 19.00	114.05 ± 21.67	0.572
Longest R-R Interval (ms)	1337.72 ± 397.77	1417.96 ± 349.84	0.154
SDNN (ms)	104.31 ± 36.21	118.74 ± 30.20	**0.004**
SDANN (ms)	92.22 ± 33.73	104.58 ± 28.38	**0.008**
SDNN Index (ms)	40.92 ± 16.02	46.99 ± 16.60	**0.015**
RMSSD (ms)	28.00 ± 20.65	30.59 ± 20.00	0.400
pNN50 (%)	6.99 ± 12.07	8.14 ± 12.27	0.534
POWER (ms^2), IQR (25-75)	1452.65 (845.60 – 2206.45)	1897.10 (1322.45 – 3007.93)	**0.004**
VLF (ms^2), IQR (25-75)	1142.30 (605.78 – 1521.40)	1331.70 (1024.48 – 2091.90)	**0.006**
LF (ms^2), IQR (25-75)	209.50 (137.05 – 346.03)	288.45 (164.23 – 537.93)	**0.007**
HF (ms^2), IQR (25-75)	87.70 (34.45 – 157.30)	106.40 (57.65 – 196.83)	**0.049**
LF/HF Ratio, IQR (25-75)	2.61 (1.62 – 4.10)	2.42 (1.61 – 3.88)	0.820

bpm: Beats per minute, DM: Diabetes mellitus, HF: High-frequency power, HRV: Heart rate variability, IQR: Interquartile range, LF: Low-frequency power, LF/HF: Low-frequency to high-frequency ratio, POWER: Total power of HRV spectrum, RMSSD: Root mean square of successive differences, SDANN: Standard deviation of the average normal-to-normal RR intervals, SDNN: Standard deviation of normal-to-normal RR intervals, pNN50: Percentage of successive R-R intervals differing by more than 50 ms, VLF: Very low-frequency power. Continuous variables are presented as mean ± standard deviation (SD), while non-normally distributed variables are expressed as median (interquartile range, IQR).

http://doi.org/10.5472/marumj.1708027
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Table IV. *Correlation analysis of HRV parameters with laboratory variables*

Variable	Value	SDNN	SDANN	SDNN Index	RMSSD	pNN50	Power	VLF	LF	HF	LF/HF
Total-C	r	-0.063	-0.028	-0.111	-0.155	-0.150	-0.098	-0.093	-0.089	-0.035	-0.055
	p	0.450	0.739	0.186	0.064	0.073	0.241	0.269	0.290	0.675	0.515
LDL-C	r	-0.279	-0.047	-0.102	-0.141	-0.132	-0.076	-0.076	-0.060	-0.015	-0.071
	p	0.349	0.576	0.224	0.092	0.117	0.369	0.366	0.477	0.862	0.402
HDL-C	r	0.220	0.230	0.110	0.018	-0.008	0.082	0.077	0.083	0.050	0.132
	p	**0.008**	**0.006**	0.189	0.832	0.922	0.328	0.364	0.322	0.552	0.117
Triglyceride	r	-0.189	-0.181	-0.167	-0.094	-0.082	-0.168	-0.146	-0.187	-0.097	-0.133
	p	**0.024**	**0.031**	**0.047**	0.266	0.332	**0.045**	0.082	**0.026**	0.251	0.113
WBC	r	-0.288	-0.287	-0.191	-0.127	-0.115	-0.169	-0.128	-0.194	-0.200	-0.099
	p	**<0.001**	**<0.001**	**0.018**	0.117	0.158	**0.037**	0.115	**0.016**	**0.013**	0.223
Hemoglobin	r	0.187	0.212	0.046	0.006	-0.024	0.045	0.051	0.037	-0.003	0.083
	p	**0.021**	**0.009**	0.576	0.941	0.770	0.584	0.536	0.651	0.968	0.311
Platelet	r	-0.184	-0.195	-0.097	-0.098	-0.099	-0.112	-0.073	-0.180	-0.122	-0.090
	p	**0.023**	**0.016**	0.231	0.227	0.225	0.168	0.367	**0.026**	0.133	0.267
HbA1c	r	-0.048	-0.085	-0.158	-0.073	-0.062	-0.174	-0.176	-0.148	-0.088	-0.014
	p	0.579	0.325	0.070	0.401	0.478	**0.045**	**0.043**	0.088	0.313	0.871
FBG	r	-0.093	-0.039	-0.173	-0.038	-0.033	-0.169	-0.173	-0.165	-0.054	-0.038
	p	0.273	0.639	**0.041**	0.654	0.696	**0.046**	**0.041**	0.052	0.526	0.658

FBG: Fasting Blood Glucose, HDL-C: High-density lipoprotein cholesterol, HRV: Heart rate variability, LDL-C: Low-density lipoprotein cholesterol, LF: Low-frequency power, LF/HF: Low-frequency to high-frequency ratio, Power: Total power of HRV spectrum, RMSSD: Root mean square of successive differences, SDANN: Standard deviation of the average normal-to-normal intervals, SDNN: Standard deviation of normal-to-normal intervals, pNN50: Percentage of successive R-R intervals differing by more than 50 ms, Total-C: Totalcholesterol, VLF: Very low-frequency power, WBC: White blood cell count

Linear regression analysis was performed to identify the predictors of SDNN, revealing that DM, HL, LV EF, and WBC count were significant predictors. However, in the multivariable analysis, only the presence of DM and WBC count remained independent predictors of SDNN (DM: β = – 17.2 [95% CI: – 27.4 to – 7.0], p = 0.001; WBC: β = – 2.1 [95% CI: – 4.0 to – 0.3], p = 0.024). Table V summarizes the results of the univariable and multivariable linear regression analyses for the predictors of SDNN.

Table V. *Predictors of SDNN in univariable and multivariable linear regression analysis*

	Univariable		Multivariable		
	Coefficient (r)	p-value	B	CI 95%	p-value
Age	0.013	0.128			
Male sex	0.001	0.816			
DM	0.112	**<0.001**	-17.2	-27.4 – 7.0	**0.001**
HT	0.008	0.250			
HL	0.054	0.002	-3.6	-13.8 – 6.7	0.491
Smoker	0.002	0.518			
CAD	0.020	0.063			
LV EF	0.037	**0.011**	-0.2	-0.4 – 0.8	0.548
WBC	0.096	**<0.001**	-2.1	-4.0 – – 0.3	**0.024**
Hemoglobin	0.024	0.066			

CAD: Coronary artery disease, DM: Diabetes mellitus, HL: Hyperlipidemia, HT: Hypertension, LV EF: Left ventricular ejection fraction, WBC: White blood cell count. Only variables with p < 0.05 in the univariable analysis were included in the multivariable model

4. DISCUSSION

In the present study, it was demonstrated that HRV parameters executes a significant reduction in elderly individuals with type 2 DM in comparison with the control group. The markedly diminished SDNN, SDANN and SDNN index values in the type 2 DM patients indicate a substantial autonomic nervous system dysfunction within this demographic. Moreover, the presence of DM and WBC count were identified as independent predictors of HRV.

This study revealed a significant reduction in HRV in elderly patients with type 2 DM. We found that time-domain HRV parameters, such as SDNN, SDANN and SDNN index, were significantly lower in individuals with DM, promoting significant autonomic dysfunction in this population. Frequency domain parameters, including LF, HF and POWER, were also reduced. In addition, the patients with DM had a higher mean heart rate and a higher minimum heart rate. These findings are consistent with previous research that has shown reduced HRV in patients with type 2 DM. For example, Kudat et al., reported lower HRV values in both time and frequency domains in diabetic patients compared to healthy subjects [12]. The Cardiovascular Disease, Living and Ageing in Halle (CARLA) study showed that HRV decreases with age and is more pronounced in people with DM [5]. The ARIC study further considered that diabetes leads to a progressive worsening of autonomic dysfunction over time, resulting in a significant reduction in HRV [13]. Similarly, Cardoso et al., found that diabetic patients with reduced HRV had a higher mean heart rate [14].

http://doi.org/10.5472/marumj.1708027
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The PROOF study emphasised the detrimental impact of metabolic syndrome on HRV, underscoring the correlation between diminished HDL levels and impaired HRV [7]. In congruence with these observations, our investigation identified a positive correlation between HDL levels and the HRV parameters SDNN and SDANN, suggesting a potential protective role for HDL in autonomic nervous system function. However, our study did not show a significant association between LDL cholesterol and HRV parameters. Absence of a significant association may be attributable to the higher prevalence of hyperlipidaemia in the DM group and the widespread use of statins, which may have resulted in a reduction in LDL cholesterol levels. While statins are effective in reducing LDL cholesterol levels, their effect on HDL cholesterol is more limited, which may provide a rationale for the observed relationship between HDL and HRV [15].

The present study demonstrated a correlation between WBC count and HRV parameters, thereby corroborating the findings of earlier research [16,17]. Aeschbacher et al., had previously demonstrated an association between WBC count and HRV, and between HRV and high-sensitivity C-reactive protein (hs-CRP) [18]. Similarly, Vinik et al., had suggested that inflammatory cytokines disrupt the balance between the sympathetic and vagal nervous systems, resulting in a decrease in HRV [19]. The negative correlation between inflammatory markers and HRV observed in this study lends support to this hypothesis.

The present study offers several notable insights into the existing literature on the subject. Firstly, a positive correlation was identified between HDL cholesterol levels and the HRV parameters SDNN and SDANN, thus providing a novel perspective on the metabolic factors that contribute to the reduction of HRV in individuals with DM. While, the PROOF study had previously demonstrated an association between low HDL cholesterol levels and decreased HRV [7], the present research offers a more specific evaluation of this relationship in elderly diabetic individuals by examining the SDNN and SDANN parameters. Furthermore, we emphasise the negative correlation between inflammatory markers and HRV, standing on the role of inflammation in assessing autonomic nervous system function in diabetic patients. This finding underscores the significance of inflammation as a key factor in autonomic dysfunction, suggesting its potential relevance during clinical evaluations of individuals with DM.

Although, previous studies have assessed HRV in elderly and diabetic patients separately, there is a lack of research evaluating both conditions together within the same population. This study contributes to the existing literature by providing a novel combined evaluation of HRV in elderly individuals with type 2 DM, addressing a gap in current research. Furthermore, we emphasize the relationship between HRV and systemic inflammation, highlighting its potential role in autonomic dysfunction.

The findings of this study indicate that HRV analysis may serve as a valuable tool for the detection of cardiac autonomic dysfunction in elderly individuals with type 2 DM. The reduction in time-domain parameters, such as SDNN and SDANN, suggests that these metrics may serve as potential biomarkers for the early diagnosis of autonomic dysfunction in this population. In addition, a positive correlation was observed between HDL levels and both SDNN and SDANN, suggesting that HDL may not only serve as a marker of cardiovascular risk but could also indicate the functioning of the autonomic nervous system. This finding emphasises the potential role of HDL cholesterol in autonomic regulation and highlights the need for further research to explore its mechanistic implications in individuals with type 2 DM.

Limitations

The present study comprises several limitations. It was not possible to assess the relationship between changes in HRV and long-term clinical outcomes. Large-scale prospective studies are required to clarify the role of HRV in predicting cardiovascular risk. Additionally, as data regarding the duration of diabetes was not available, it was not possible to evaluate its impact on HRV. While prior studies have demonstrated that autonomic dysfunction worsens with extended diabetes duration, the present study was unable to ascertain the extent of this relationship.

As the HRV measurements were obtained from 24-hour Holter recordings, the influence of daily activities, stress, and environmental factors could not be entirely controlled. It is hypothesised that measurements taken at different time intervals might more accurately reflect the dynamic changes in autonomic function. Furthermore, it is acknowledged that the use of medications such as beta-blockers and ACE inhibitors may affect HRV; however, the specific impacts of these drugs were not analysed in detail. It is also worthy of noting that the reduction of LDL cholesterol levels by statins could have complicated the evaluation of the relationship between LDL cholesterol and HRV. Nevertheless, the positive association between HDL cholesterol levels and HRV underscores the significance of metabolic factors in the regulation of the autonomic nervous system.

Conclusion

This study demonstrates that elderly individuals with type 2 DM exhibit significantly diminished HRV, indicative of CAN and heightened cardiovascular risk. The negative correlation between HRV parameters and inflammatory markers suggests a potential role of systemic inflammation in this impairment. These findings underscore the significance of HRV analysis as a tool for early detection of CAN in diabetic patients, which could facilitate risk stratification and the development of preventive strategies. Future studies should validate these associations in larger cohorts and explore therapeutic interventions to mitigate autonomic dysfunction in type 2 DM.

Compliance with Ethical Standards

Ethical approval: This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by Marmara University, School of Medicine Ethics Committee,

http://doi.org/10.5472/marumj.1708027
Marmara Med J 2025;38(2): 108-113

Istanbul, Turkiye, (date: 31/01/2025, approval number: 9.2025-25-0060).

Conflict of interest: The authors declare that there is no conflict of interest.

Financial support: This study received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Author contributions: MD: Writing – reviewing and editing, writing – original draft, validation, resources, project administration, methodology, investigation, formal analysis, data curation, visualization, supervision, conceptualization.

FS: Writing – reviewing and editing, validation, resources, methodology, investigation, formal analysis, data curation , writing – reviewing and editing, visualization. Both authors read and approved the final version of the manuscript.

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